CUYAHOGA VALLEY NATIONAL PARK
Programmatic Environmental Assessment for Riverbank Management of the Cuyahoga River

Appendix I

Supplemental Detail and Description of Conditions: Riverbank Management Alternative

Introduction

This appendix explains in more detail some of the techniques that are proposed as recommended actions under the various conditions (A, B, C, D, and E) for each alternative. The descriptions below are intended to be used in conjunction with Tables 3-1 and 3-2, however, they relate in particular to the conditions found on Table 3-2 for the Riverbank Management Alternative (Alternative 2).

Condition A

Condition A provides techniques to monitor riverbank conditions using an expanded set of tools. Riverbank recession under Alternative 1 is monitored by measuring the distance from driven steel pins to the edge of the river bank in one or more locations per site. Additional techniques under the Riverbank Management Alternative include: Geographic Information System (GIS) mapping and add-on tools to predict riverbank recession; using Global Positioning System (GPS) instruments to obtain more edge of riverbank points within a site; and for very steep and high banks, a slope stability evaluation.

GIS Mapping and Migration Predictor Tools

The National Cooperative Highway Research Program (NCHRP) Project 24-16, "Methodology for Predicting Channel Migration" provides a useful tool for tracking historic channel migration and predicting future channel migration.[1] Channel migration includes lateral channel shift (expressed in terms of distance moved perpendicular to the channel center line, per year) and down valley migration (expressed in distance moved along the valley, per year). The method uses 1964 (and earlier) and 2000 (or more recent) aerial photography for Summit County; and 1969 (and earlier) and 1999 (or more recent) aerial photography for Cuyahoga County within ArcView® (Version 3.2 or higher), supplemented with two ArcView extensions that can be purchased from a private vendor. Aerial photographs are first registered, and a riverbank GIS file (.shp) is digitized for each set of historic or current aerial photography that is used in the evaluation. With this information a series of time elapsed maps is prepared and organized for

[1] See Lagasse et al, 2003a; Lagasse et al, 2003b and the following link for more information: http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+24-16

ArcView is a trademark of Environmental Systems Research, Inc., registered in the United States and certain other countries; registration is pending in the European Community.

each location showing the spatial extent of Cuyahoga River migration, using the Data Logger extension. The historic information can be used with the Channel Migration Predictor to predict future channel migration. Researchers have found that channel migration rates in alluvial rivers reach a maximum of between 10 and 20 percent of channel width for bend radius-to-width ratios (R_c / W) of between 2 and 3. A more complete discussion of NCHRP Project 24-16 may be found in Lagasse et al, 2003a and Lagasse et al, 2003b.

GPS Datalogging
Global Positioning System equipment can be used to obtain an array of top-of-riverbank points at a given time so that a history of meander migration towards a resource can be recorded. The GPS measurements would be used to supplement the measurements from fixed pin locations. Although less precise than fixed measurements, the GPS data could provide a better overall view of trends along the riverbank, and can be incorporated into CVNP GIS. Grouping the data by date will enable the mapping of historic trends from successive GPS loggings. Either CVNP staff or outside contractors can obtain edge of riverbank points as a part of site visits or a more formalized program.

Slope Stability Evaluation
Slope stability evaluations may be necessary for some sites with very high and steep banks that could be subject to deep rotational failures. Performance of these evaluations requires surveyed cross sections and soils samples. This information is then input to a slope stability computer program (such as STABL6) to determine factors of safety for existing conditions. Sites with factors of safety that approach 1.0 should be identified and moved to Condition D to provide direct measures to repair and stabilize the slope.

Condition B
Condition B will involve the evaluation and application of what are generally considered indirect measures. Indirect measures are engineered or non-engineered measures that can be applied in locations where the progress of riverbank erosion has not yet presented an immediate threat to the Towpath Trail, Valley Railway or other recreational feature. Indirect measures most often involve the use of new plant material, large woody debris (LWD), tree management, and sometimes riprap. Since most of these approaches have not been utilized at CVNP, descriptions, references, photos and example details for many of these features are provided below.

Large Woody Debris (LWD)
Large woody debris (LWD) is naturally occurring pieces of wood larger than 10 feet in length and six inches in diameter. It provides an important habitat component in streams, particularly low-gradient streams. Projects or improvements involving LWD can be referred to as either Category 1 or Category 2. Category 1 projects improve habitat by increasing LWD quantities in streams. Category 2 projects involve using LWD to alter flows to improve aquatic habitat. Examples of specific riverbank management objectives that can be accomplished with Category 2 projects within CVNP include diverting flows away from a streambank to reduce erosion, and armoring streambanks to reduce erosion. Removal of LWD from the Cuyahoga River system is not recommended. If removal of LWD from a particular location is necessary, and cannot be used for one of the two aforementioned management objectives, then it should be reconfigured

by moving it to a location where it will not aggravate riverbank erosion and where it can enhance habitat. A more complete discussion of the uses and benefits of LWD may be found in found in Fischenich and Morrow, 1999).

Root Wad Composites

Root wad composites are combinations of interlocking tree materials consisting of a rootwad and other tree parts in combination with various revegetation methods used to provide bank stabilization and habitat enhancement. Rootwad composites reduce the stream energy adjacent to a riverbank and create streambed scour away from the bank that provides cover and substrate for aquatic organisms. The rootwad composite consists of: rootwad with tree trunk (bole), footer log, bank log, habitat limbs and tops and vegetation, as shown in Figures I-1 and I-2. The configuration and spacing of rootwad composites are similar in many respects to spurs and bendway weirs. A more complete discussion of the design of rootwad composites may be found in Sylte and Fischenich, 2000.

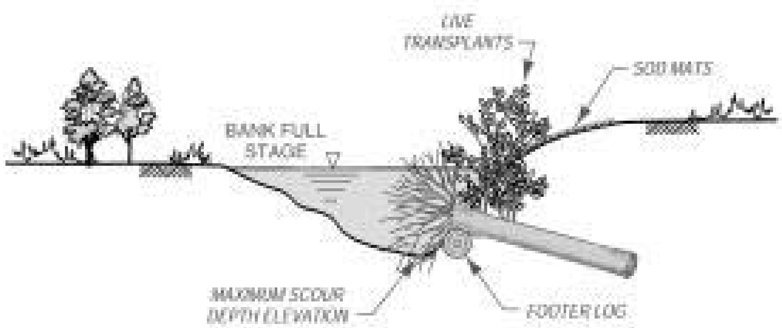

Figure I-1. Rootwad Elevation View (from Sylte and Fischenich, 2000).

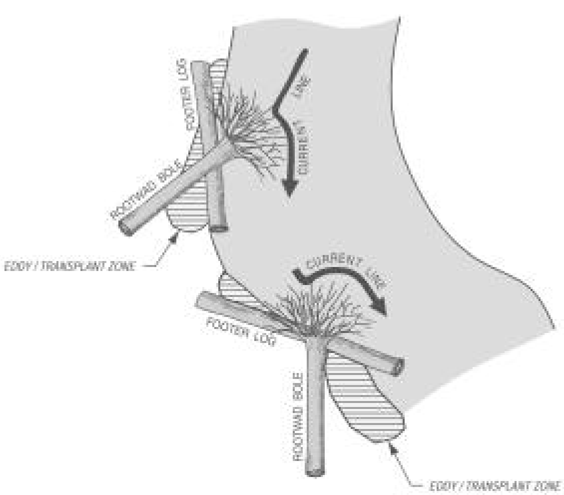

Figure I-2. Rootwad Plan View (from Sylte and Fischenich, 2000).

Riparian Corridor Plantings
Establishment of a well-vegetated riparian stream corridor provides streambank stability and habitat enhancement benefits. The USDA Natural Resources Conservation Service has been a leader in the development of stream corridor restoration practices.[2] Chapter 8 of "Stream Corridor Restoration: Principles, Processes and Practices" (USDA, 2001) contains specific guidance on riparian corridor plantings. Researchers have also evaluated the increase in soil strength from various tree species due to root reinforcement and the hydrologic effects of riparian vegetation on riverbank stability (Collison and Simon, 2001a and Collison and Simon, 2001b).

Live Stakes and Live Posts
Live stakes and live posts consist of branch cuttings from freshly cut dormant plants. They create a living root mat that stabilizes the soil by reinforcing and binding the soil particles together and by contributing to the reduction of excess soil moisture. Live stakes and posts are living, woody plant cuttings capable of rooting with relative ease. The cuttings are large enough and long enough to be tamped into the ground. They are intended to root and grow into mature shrubs that, over time, will serve to reinforce and stabilize the soils and produce vegetative growth. This is an effective stabilization method for simple minor erosion problems. Once the roots and vegetation have become established, they are able to function in soil reinforcement and stabilization. The technique is effective when the construction time is limited and an inexpensive and simple method will handle the repair. This is an effective system for securing natural geotextiles such as jute mesh, coir, or other blanket surface treatments. This is a good combination for areas which would benefit from both treatments. After they have become well established, live stakes and posts are effective in camouflaging an open area. They usually enhance the development of healthy habitat areas over time. These installations also reinforce the soil mantle and provide surface protection via the top leaf growth and leaf litter. Live stakes and live posts are typically placed in a triangular pattern between two and five feet apart depending upon the diameter of the branch cuttings. Figure I-3 shows a live stake planting detail. Figure I-4 shows a post plant spacing detail.

[2] See http://www.usda.gov/stream_restoration .

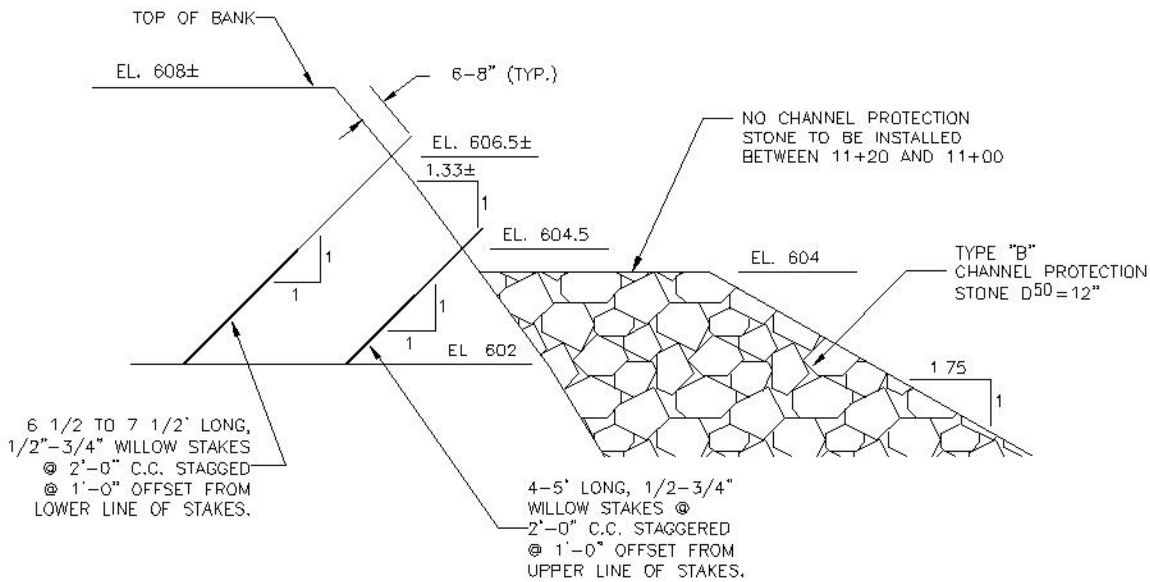

Figure I-3. Example Live Stake Planting Detail.

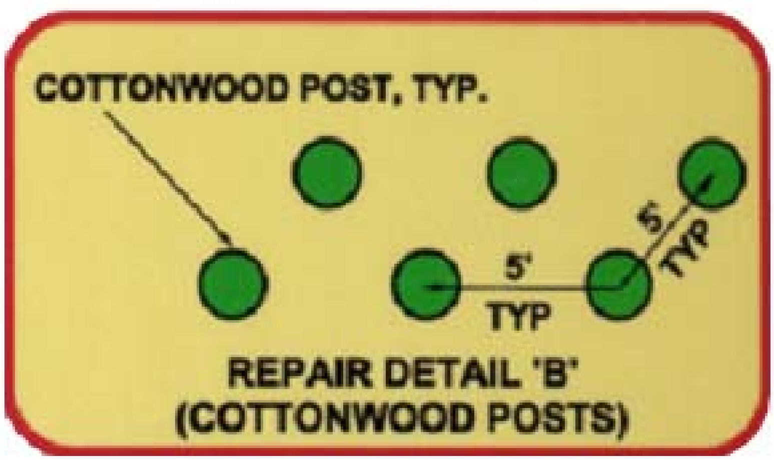

Figure I-4. Example Live Post Planting Plan Layout

Live Fascines

Live fascine structures are bound sausage-like bundles of live cut branches. They are tied together securely and placed into trenches along streambanks, upland slopes, wetlands, shorelines, or directly into gully sites. The live fascine bundles are typically installed with live stakes and dead stout stakes, and are often used in conjunction with erosion-control fabrics. Normally, they are placed on contour in dry sections, or at an angle in wet sections on the slope face. They are shallowly installed and usually create very little site disturbance as compared with other methods. Live fascines perform several "living systems" and mechanical "protective" functions in the erosion control process and hydrology process. They break up the slope length into a series of shorter slopes separated by benches; provide surface stability for the planting or natural invasion and establishment of vegetation; trap debris, seed, and vegetation on the slope face; slow surface-water velocity and allow for more infiltration; assist in drying excessively wet sites through transpiration as they root and produce top growth; and reinforce the soil mantle via the root systems. These rebuilding structures offer reasonably inexpensive and immediate surface protection from erosion when properly used and installed. Whether they survive or not, live fascines are effective in reducing erosion on slopes and shallow gully sites. They are a very effective stabilization technique, especially once rooting is established. Live fascines are capable of holding soil on the face of a streambank or upland slope by creating mini-dam structures. A typical detail of a live fascine is shown in Figure I-5. A more complete discussion of the design of live fascines may be found in *The WES Stream Investigation and Streambank Stabilization Handbook* (Biedenharn et al, 1997).

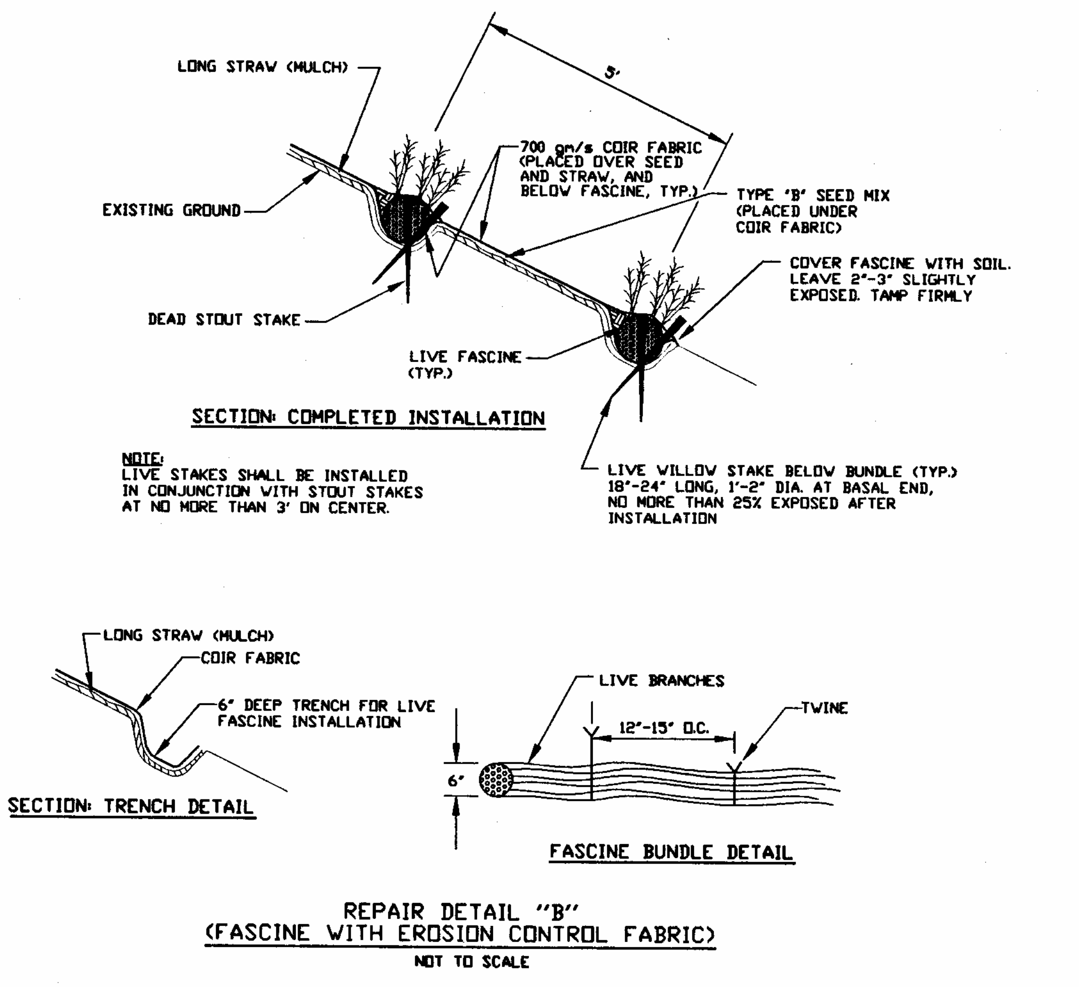

Figure I-5. Live Fascine Details.

Engineered Log Jams
Engineered log jams are a relatively new technology that has been used by the U. S. Forest Service and others to protect features (typically roads) adjacent to streams and rivers. Engineered log jams use natural structures that emulate natural riverine processes to protect roadways adjacent or parallel to river channels. Engineered log jams are usually placed in series, in combinations, or in pre-selected channel reaches. Log jam structures can: (1) stabilize channel banks and protect roads using native materials, (2) deflect and catch large woody debris in transport, (3) promote establishment of vegetated riparian areas (channel banks and in-channel riparian islands), (4) improve or create new fish habitats, and (5) restore or maintain the aesthetic or natural character of the river. The construction of engineered log jams require the following detailed site and survey information: channel longitudinal profile, pool survey, wood survey and, channel bottom pebble counts. Additional information includes channel hydraulic and scour analyses, along with a geomorphic analysis to formulate site design. Figure I-6 shows an example design concept for an engineered log jam, and Figure I-7 is a photograph of a completed engineered log jam.

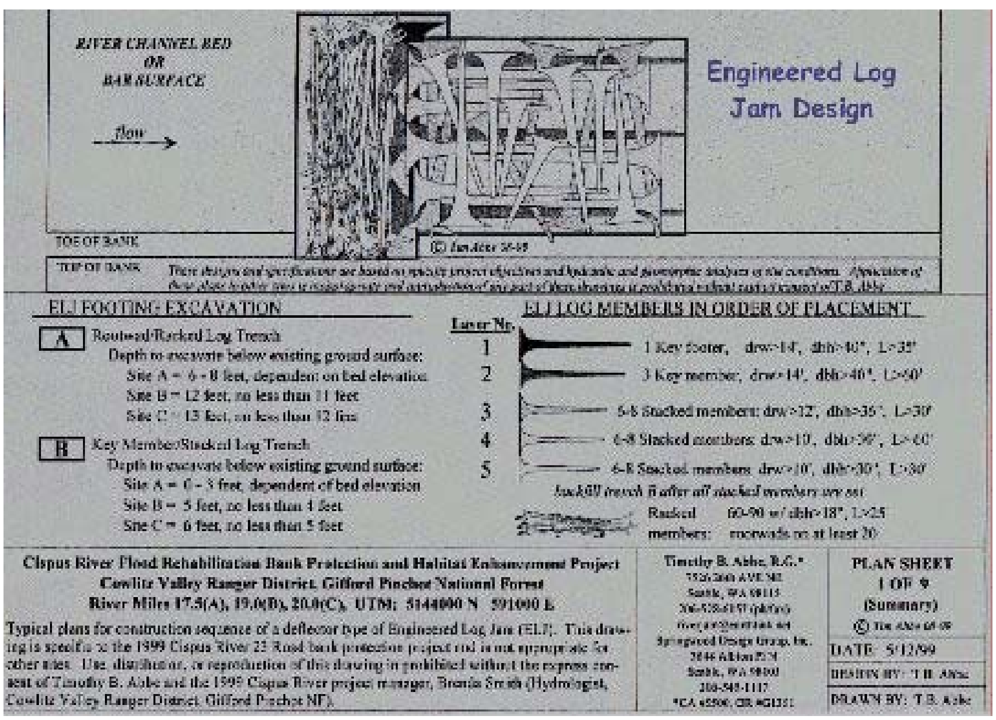

Figure I-6. Example Design Concept for Engineered Log Jam (U.S. Forest Service).

Figure I-7. Engineered Log Jam (U.S. Forest Service).

Timber Weirs

Timber weirs are devices constructed primarily of fallen trees, logs or recently cleared trees that are stacked and spanned between posts to form a weir, and are often used to hinder flow in channel cutoffs that may present a risk to a cultural resource at some time in the future. A typical detail of a timber weir is shown in Figure I-8.

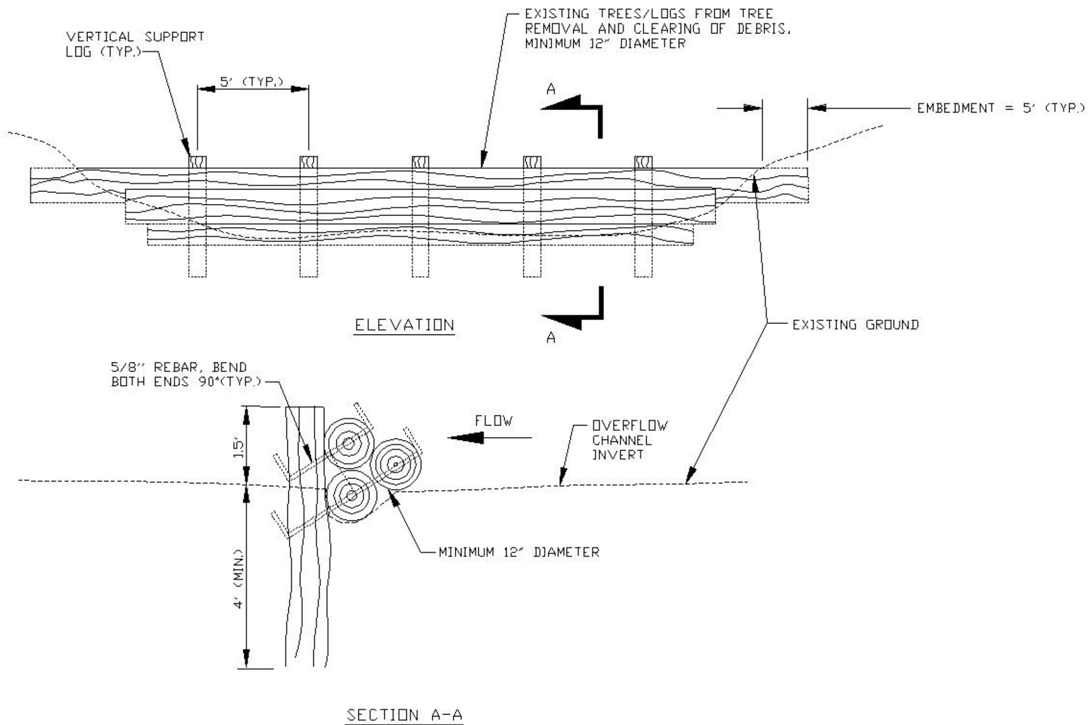

Figure I-8. Timber Weir Detail.

Tree Management

Tree management is a preemptive means of addressing streambank erosion that involves removal of existing, large diameter trees that are at risk of being undercut by the erosive action of a watercourse. When large diameter trees located at the river's edge are eventually undermined and fall into the river, they tend to expose a significant length of unprotected riverbank that is quickly eroded. Furthermore, once they have fallen into the river, they often redirect flows towards the unprotected riverbank, thus aggravating riverbank erosion. As part of the Riverbank Management Program, CVNP is adopting a tree management plan that involves cutting trees that are larger than 9 inches in diameter (leaving the roots in place), that are either greater than 50% undercut by the watercourse, or that are tilted more than 45 degrees towards the watercourse. Whenever a tree is removed six (6) live stakes or posts will be planted above the dominant discharge elevation to help revegetate the bank.

Encouraging Meander Cutoffs

An avulsion is a sudden change in the river channel course that usually occurs when a stream breaks through its banks. A cutoff is an avulsion related to a single meander loop and can be defined as a natural or artificial channel that develops across the neck of a meander loop (a neck cutoff) or across a point bar (chute cutoff). Meander bends eventually cut off when the radius of curvature (R_c) becomes too short, primarily the result of the arrest of one limb of the bend by more erosion-resistant material. A reduced hydraulic slope causes a reduction in sediment-transport capacity in the upstream portion of the bend and thus increases the frequency of flows over the meander loop, which leads to cutoff development and eventually bend cutoff. Researchers identified a dimensionless cutoff index based on a review of cutoffs in the Sacramento River (WET, 1988 and Harvey, 1989). Two other important conditions that were identified by the researchers were the presence of mid-channel bars in the upstream limb of the bend and the presence of chute channels across the point bar. The implication of the research is that by artificially reducing the resistance in meander cutoffs that are forming, and by increasing the resistance in the upstream limb of the bend, meander cutoffs could be encouraged to occur sooner. Encouraging meander cutoffs, rather than working against nature, is a means of accelerating a natural process. Meander cutoffs can also have significant impacts within the channel reach that need to be examined. These include: accelerated erosion of adjacent bends, especially the bend immediately downstream; degradation in the upstream channel reach; and aggradation in the downstream channel reach.

Reestablish Channel Meanders
Reestablishing channel meanders is the opposite of encouraging meander cutoffs. Since reestablishing channel meanders is more likely to be working in opposition to nature, it is less likely that that this option will be either desirable or feasible for the NPS to implement in CVNP.

Improve Bank Drainage
Bank failure is primarily caused by fluvial erosion (entrainment of grains or aggregates by the flow) in combination with mass failure (slumping or sliding due to gravity). The mass failure mechanism is enhanced when the water table is high relative to the water level in the stream or river. If the high water table is occurring because of an inadequate surface or subsurface drainage system, then improvements to these could help reduce the rate of mass wasting of the riverbank. Improvement of subsurface drainage is the key to preventing wet earth flow failures. Steps involved include the reduction of seepage pressures by encouraging free drainage, with a suitable filter installed to prevent piping erosion. Drainage may be achieved using perforated pipes or French drains. Filters may be granular, geotextile or vegetative. This is a serious form of instability that will require a geotechnical site survey to establish the details of the problem and a careful analysis of bank seepage to support the selection of an appropriate solution. In some cases, regrading an impeded surface drainage system could reduce the water table. Prior to implementing such improvements, a check should be made to determine if changes to the surface and subsurface drainage would have detrimental effects on wetlands.

Longitudinal Peaked Stone Toe Protection (LPSTP)
Longitudinal Peaked Stone Toe Protection (LPSTP) is a continuous, triangular shaped stone dike placed longitudinally at, or slightly streamward of the toe of an eroding bank. It typically utilizes 1 to 2 tons of rock per linear foot and varies based upon the depth of scour at the toe, estimated stream forces on the bank, and flood durations and stages. Longitudinal Peaked Stone Toe Protection must be keyed into the bank at both the upstream and downstream ends of the protection. Tiebacks are intermediate stone features that connect the LPSTP to the bank at regular intervals, and are the same height as the LPSTP or elevated slightly towards the bank end and are keyed into the bank. Long tiebacks should be angled upstream to act as bendway weirs. Figure I-9 shows an LPSTP installation. A more complete discussion of the design of LPSTP may be found in *The WES Stream Investigation and Streambank Stabilization Handbook* (Biedenharn et al, 1997).

Figure I-9. Longitudinal Peaked Stone Fill Protection (LPSFP) (Biedenharn et al, 1997).

Longitudinal Fill Stone Toe Protection (LFSTP)

Longitudinal Fill Stone Toe Protection (LFSTP) is similar to LPSTP, except that instead of coming to a peak, the crest has a specified width. Therefore, LFSTP has a trapezoidal cross section rather than a triangular cross section. In areas of deep scour, LFSTP provides sufficient rock to self adjust, or launch into the scour hole, while still maintaining its original crest height. An example LFSTP is shown in Figure I-10. A more complete discussion of the design of LFSTP may be found in *The WES Stream Investigation and Streambank Stabilization Handbook* (Biedenharn et al, 1997).

Figure I-10. Longitudinal Fill Stone Toe Protection (LFSTP) (Biedenharn et al, 1997).

Condition C

Condition C type repairs may include replacement of any existing riverbank stabilization features damaged or undermined by natural river processes, or the upstream or downstream extension of any existing riverbank stabilization measures with typically the same repair detail. The most common types of existing riverbank stabilization measures within CVNP include:

- Stacked gabions
- Continuous riprap toe without vegetative plantings above the top of riprap
- Continuous riprap toe with vegetation (brush layering, live stakes, or Vegetation Reinforced Soil System) above the top of riprap.

The repair and extension of these existing types of riverbank stabilization measures are discussed below. At any Condition C site, the potential for using riprap spurs, bendway weirs, engineered log jams or other suitable measures to augment existing protection will be examined. An essential aspect of ensuring the long term functionality of longitudinal repairs is to make sure they are adequately keyed into the bank or naturally hardened zones along the bank at the upstream and downstream limits. *The WES Stream Investigation and Streambank Stabilization Handbook* provides guidance on the design of all these measures.

Stacked Gabions

Stacked gabions, as shown in Figure I-11, have been used in several areas adjacent to the Towpath Trail. Gabions are rock-filled wire or synthetic baskets that are wired together to form continuous structures. The mesh is typically galvanized or coated with polyvinyl chloride to reduce corrosion. Gabions can use lower quality stone than riprap structures and can be placed on steeper slopes. Gabion structures are flexible enough not to be vulnerable to minor bank shifts but need to be placed on a firm foundation. Gabions may also be used to construct deflective structures, and would have the same impacts as jetties or hardpoints when constructed as such. Sediment is usually deposited among the rocks in gabion structures, and vegetation often becomes established so that the structure is obscured and the stream has a natural appearance. Unvegetated gabions are similar in appearance to masonry work, which may be visually pleasing in some settings. The steep slopes on which gabions are sometimes placed may hinder wildlife access. Gabion structures can be designed with artificial overhangs, flow deflectors, and other features to enhance fish habitat. Failed baskets may be hazardous to recreationists, especially canoeists. Gabions have been widely used for streambank protection on streams located in a variety of environments in the US and Europe. They are most frequently used in urban areas, particularly on small watersheds where high flood conveyance is desired. Gabion streambank protection structures have performed very well in some settings. The major problem is basket failure, a problem that is aggravated by ice and other debris, gravel bedload movement, vandalism, and corrosive streamflows. Gabions are usually cost prohibitive when compared to riprap structures, but instances may occur when they are a preferred alternative. Stacked gabions are prone to slumping from undermining at the toe, flanking and deformation due to failure of the wire baskets. Although gabions are not a preferred method of riverbank stabilization in CVNP, there will continue to be a need for these structures. One improvement that can be made to these features is to set the lowest row of the gabion system on a designed riprap toe that provides an erosion resistant foundation. Another is to install brush layers between the rows of baskets to establish woody vegetation that will increase the stability and longevity of the gabion structures, while enhancing habitat and aesthetics.

Figure I-11. Stacked Gabions at CVNP.

Continuous Riprap Toe Without Vegetative Plantings Above the Riprap

A continuous riprap toe repair, shown in Figure I-12, has been utilized in a number of locations adjacent to the Towpath Trail and Valley Railway. These types of repairs are subject to undermining at the toe and flanking, therefore they will need to be repaired or extended from time to time. These types of features can be improved by limiting the height of the riprap to an elevation no greater than the dominant discharge, and possibly as low as the mean discharge if shear stresses are low, and providing vegetation in the form of brush layers, live stakes, and Vegetation Reinforced Soil System (VRSS) above the top of riprap.

Figure I-12. Continuous Riprap Toe Without Vegetative Plantings Above at CVNP.

Continuous Riprap Toe With Vegetative Plantings Above the Riprap

A continuous riprap toe repair with vegetative plantings, shown in Figure I-13, has been utilized in a number of locations primarily adjacent to the Towpath Trail. These types of repairs are also subject to undermining at the toe and flanking, therefore they will need to be repaired or extended from time to time. The riprap in these features has typically been designed to an elevation no greater than the dominant discharge, and possibly as low as the mean discharge where shear stresses are low. One significant improvement to these features can be made by providing additional riprap in the form of a launched stone toe where toe scour is anticipated. Another is the provision of hardier vegetation in the form of live stakes, brush layers and VRSS above the top of riprap. Improvements in the hardiness of vegetation can be made by improving the quality control in connection with harvesting, storage, and installation of live, dormant plant material.

Figure I-13. Continuous Riprap Toe With Vegetation Above Top of Riprap at CVNP.

Other Features
When extending an existing repair upstream or downstream, trenchfills or windrows may be appropriate design features to use in connection with Condition C repairs. A trenchfill revetment is a standard stone armor revetment with a large toe. It is normally constructed in an excavated trench behind the river bank, in anticipation that the river will erode to the revetment, causing the stone toe to launch down and armor the subaqueous bank slope. This allows stabilization along a predetermined alignment, and is often simpler to design and construct than revetment placed on an active streambank. Since all but the top of the revetment is buried, it may not be noticeable and may eventually be overgrown with vegetation. A windrow revetment consists of rock placed on the floodplain surface landward from the existing bankline at a predetermined location, beyond which additional bank erosion is prevented. Since it involves no excavation, it is simpler to construct than a trenchfill revetment, but is very visible because it is not buried.

Condition D
Condition D will generally involve the evaluation and application of what are generally considered direct measures. Direct measures are typically engineered measures that are applied in locations where the progress of riverbank erosion presents an immediate threat to the Towpath Trail, Valley Railway or other recreational features. Direct measures almost always involve the use of riprap in some form with provision of new plant material above the elevation of the dominant discharge or the mean discharge depending upon shear stresses acting on the bank. Descriptions, photos and example details are provided below. The most common types of direct measures (other than those previously discussed) that have been or could be applied within CVNP include:

- Riprap toe with bioengineered features (eg. VRSS, brush layering, live stakes, live fascines) above that point to the top of bank;

- Riprap spurs anchored to the resource and aligned according to the channel plan form and stream characteristics;
- Bendway weirs anchored to the resource and aligned according to the channel plan form and stream characteristics; and
- Mechanical stabilization of the bank through soil retention and drainage.

An essential aspect of ensuring the long term functionality of these repairs is to make sure they are adequately keyed into the bank or naturally hardened zones along the bank at the upstream and downstream limits. *The WES Stream Investigation and Streambank Stabilization Handbook* provides guidance on the design of all these measures (Biedenharn et al, 1997).

Riprap Toe with Bioengineering Features

Cuyahoga Valley National Park has utilized several combinations of a riprap toe and bioengineering measures above. Figures I-14 and I-15 show the typical section and photograph of the Vegetation Soil Reinforced System (VRSS). The VRSS is useful for the reconstruction of steep fill slopes. It is a complex method that requires a team with extensive knowledge and understanding of site assessment (specifically geotechnical and hydrological factors), reasons for use, and methods of installation to ensure immediate and long-term success in developing functionality. Similar to brushlayer fill, it involves the cutting and placement of live rooted plants or live branch cuttings in regular arrays in the face of a reconstructed slope. The branches or items are oriented perpendicular to the slope. This orientation, along with the addition of geogrid, offers significant reinforcement to the soil mantle. The geogrid is both used within the fill as well as wrapped around the face of each soil lift. It is a method that is useful for upland slopes, stream and riverbanks as well as shoreline areas, to solve more complex, deeper instability as well as higher velocity conditions. The VRSS consists of placing grid and branches on prepared lifts of soil. The soil lifts between the branches are wrapped with grid. The contribution of branches and grid offer immediate soil reinforcement to the newly constructed slope. The protecting branches assist in retarding runoff and surface erosion, as well as reducing velocities from flowing water. The installed branches are intended to grow, producing roots and leaves. The same type of design can be accomplished using live stakes, live posts, live fascines or brush layering.

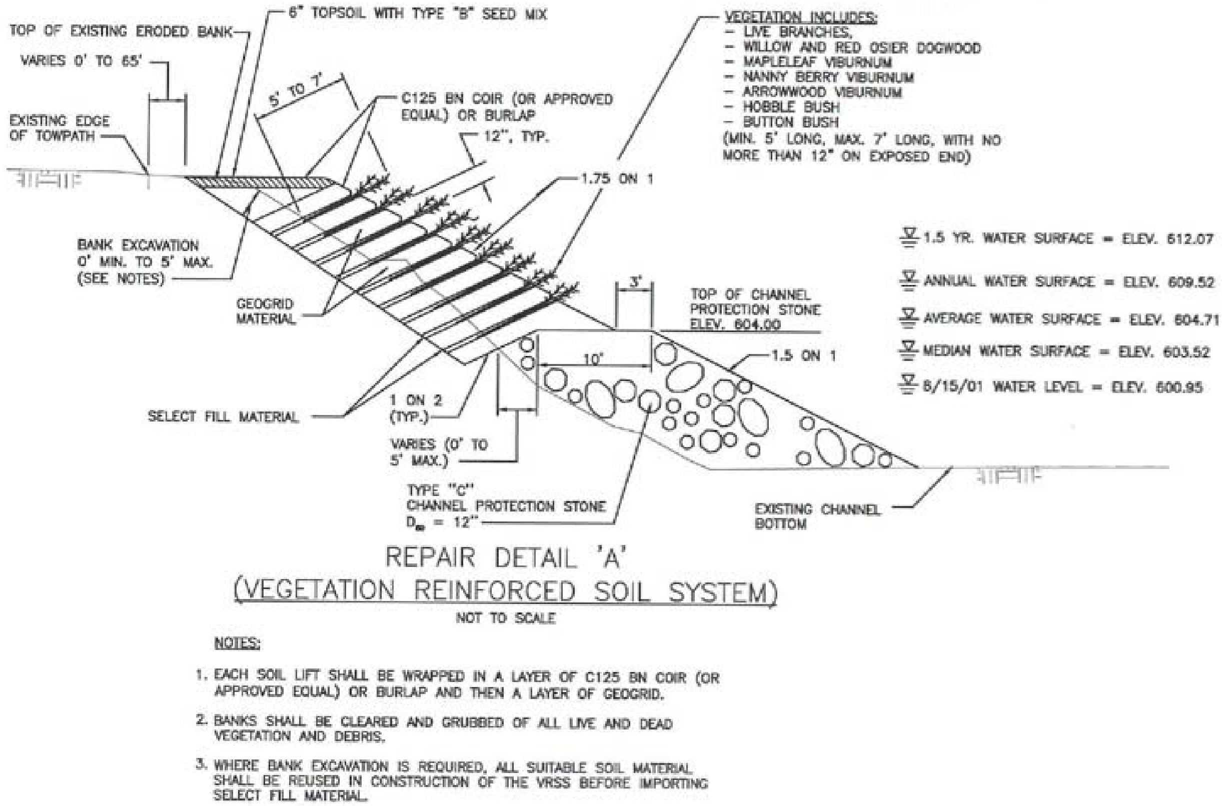

Figure I-14. Vegetation Reinforced Soil System (VRSS) Typical Section

Figure I-15. Vegetation Reinforced Soil System (VRSS) 6 months after construction at CVNP

Hardpoints, Spurs and Bendway Weirs

The terms hardpoint and spur are generally regarded as being synonymous. However, for this appendix, the terms are used to differentiate between differing degrees of the same basic structures. Both structures consist of a stone or soil protrusion that extends riverward of and perpendicular to the bank, and a stone root to prevent flanking of the structure. Hardpoints are low stubby structures that are frequently overtopped and extend riverward less than 15 or 20 feet. Spurs are generally constructed to the height of the high bank, and extend riverward more than 20 feet. Hardpoints deflect the current away from the eroding bank for only a short distance, with no attempt to change the general alignment of the river. By contrast, spurs deflect current for a considerable distance, and are often intended to alter the main flow of the river. Hardpoints and spurs are best suited to long straight reaches of river, or on the convex bankline of meanders. Structures placed on the concave bank can fail from excessive scour between structures. The main advantage of hardpoints and spurs is the low quantity of material needed to protect a given bank relative to other structural alternatives. The environmental benefits of this structure type are primarily related to fisheries and recreation. Hardpoints and spurs create a habitat diversity not found with most other structure types. Scour off the end of the structure creates deep pools and high velocity flows. Scallop areas of shallow, relatively slow-moving water provide additional habitat diversity downstream of the structures. Spurs are typically visible above normal water elevation. Although generally transverse to the flow, riprap spurs may be angled slightly upstream. Riprap spurs have been constructed in CVNP at Station 940 of the Towpath Trail as shown in Figures I-16 through I-19.

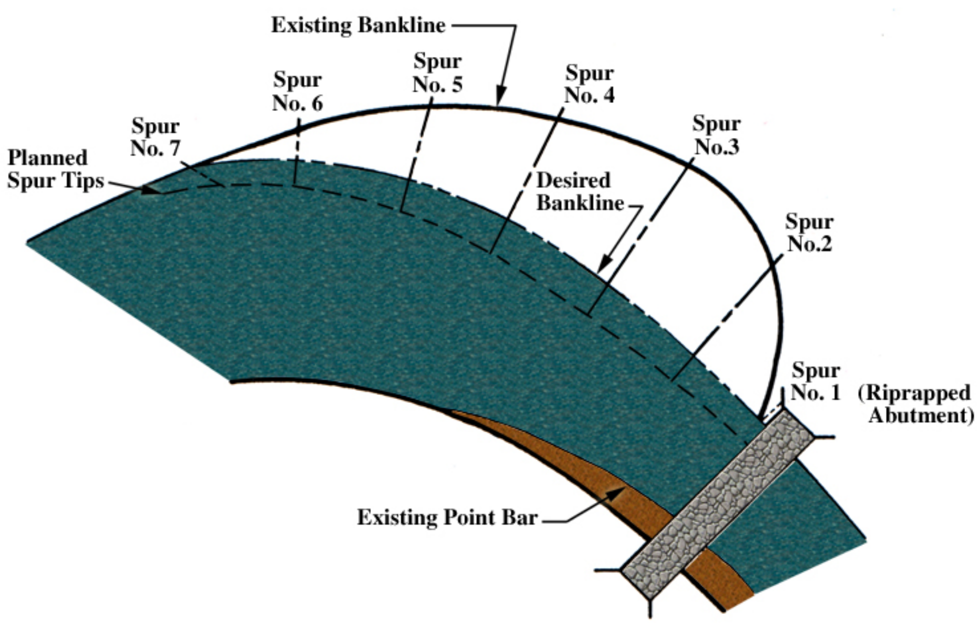

Figure I-16. Riprap Spur Location Plan For Reestablishing A Bankline.

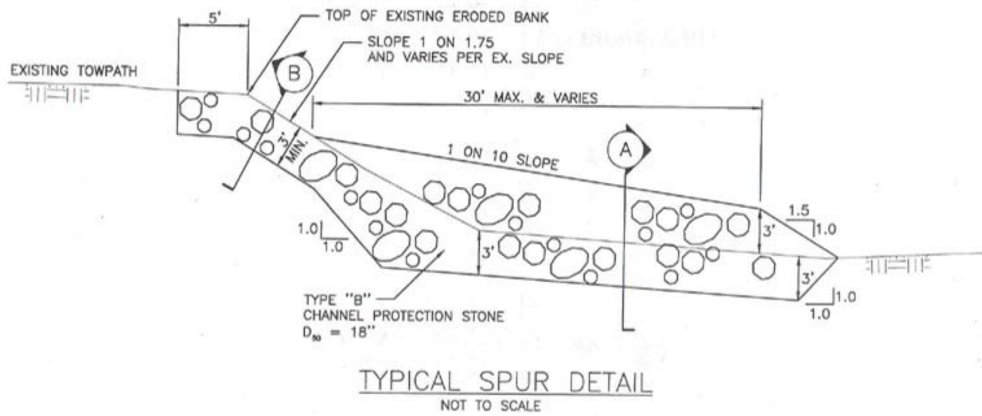

Figure I-17. Riprap Spur Detail.

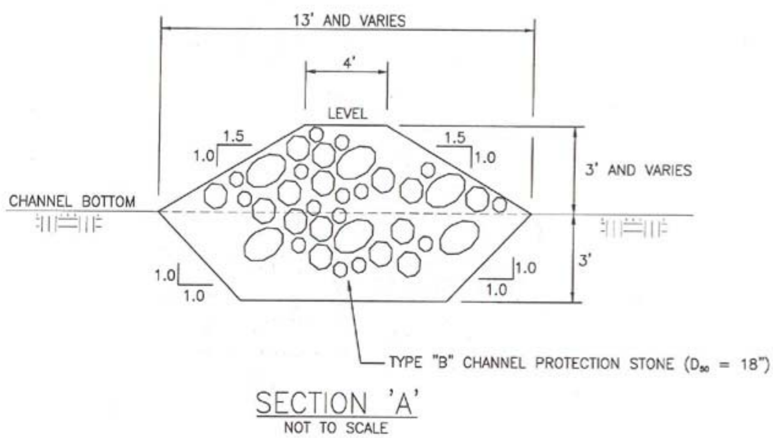

Figure I-18. Riprap Spur Detail – Section 'A.'

Figure I-19. Riprap Spurs Constructed Along Outside Bank of Cuyahoga River at CVNP.

Bendway weirs, sometimes referred to as vanes, are structures placed within the channel at a slight angle to the normal flow that reduce the secondary currents and thus reduce the erosive capacity of the river. The two most common types of bendway weirs are Iowa Vanes and stone weirs. Iowa Vanes are small flow-training structures (foils), designed to modify the near-bed flow pattern and redistribute flow and sediment transport within the channel cross-section. The structures are typically installed at an angle of 15-20° to the flow, with a height of 0.2 - 0.4 times local water depth at designed stage. The bendway weirs function by generating secondary circulation in the flow. The circulation alters magnitude and direction of the bed shear stresses and causes a change in the distributions of velocity, depth, and sediment transport in the area affected by the bendway weirs. As a result, the river bed topography may be altered by selective layout of the structures. Stone bendway weirs are low stone structures angled approximately 15 – 30° normal to the flow. They are overtopped by all but the lowest flows. Because bendway weirs stop erosion by modifying secondary circulation, no bank sloping or treatment is necessary. Aquatic benefits are not destroyed, and once vegetation becomes re-established on the eroding bank, riparian habitat and aesthetic benefits are improved. During low water, the weirs are not very appealing visually, and there may be some hazard to navigation and to recreationists using the stream. Bendway weirs have been used successfully to ameliorate shoaling problems at water intakes and bridge crossings.

Mechanical Stabilization of the Bank Through Soil Retention and Drainage
Slope failures caused by fluvial erosion adjacent to steep banks, similar to that shown in Figure I-20 require repair of the eroded slope adjacent to watercourses. To repair the slope and maintain the stream invert, often requires mechanical stabilization of the slope at a steeper angle than can be maintained in nature without deep rooted vegetation. For situations such as this, a geosynthetic reinforced soil embankment, cellular confinement embankment, shown in Figure I-21, or other mechanical stabilization method repair is needed. In Figure I-21, the mechanically stabilized slope can be constructed to a 1.5H:1V slope. A turf reinforcement matting is used on the slope to provide a protected surface for establishment of turf
.

Figure I-20. Bank Failure Needing Mechanical Stabilization.

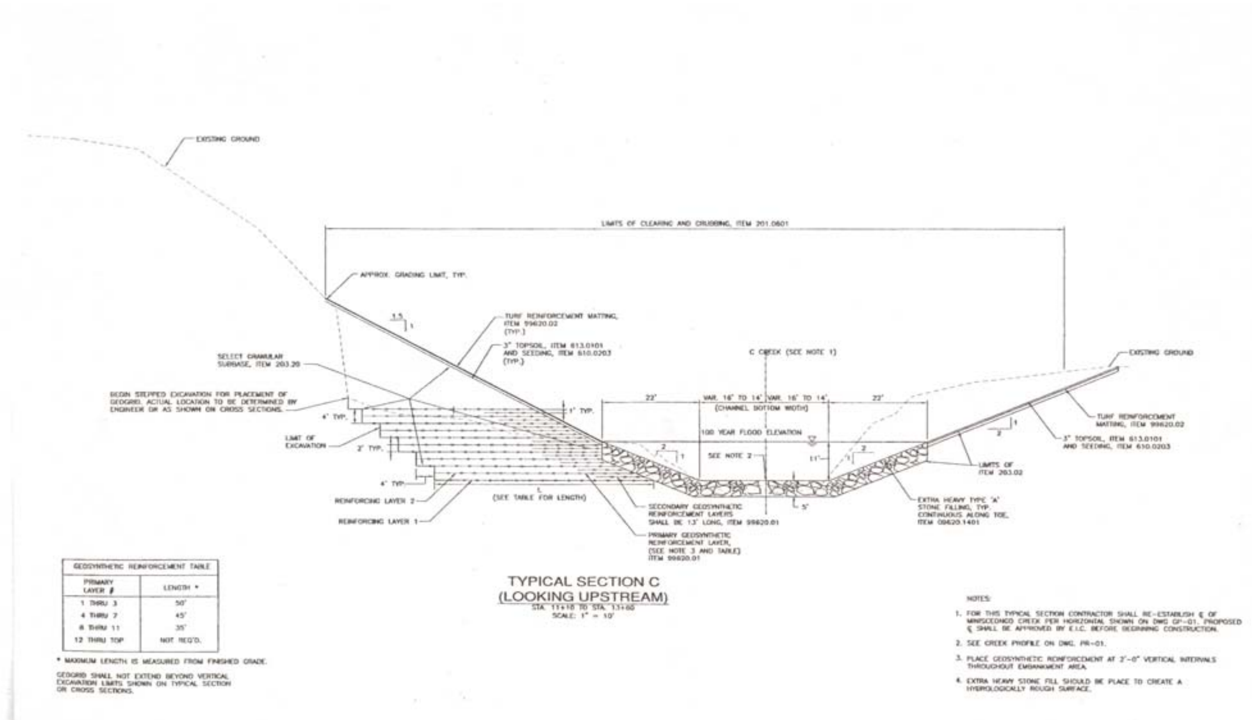

Figure I-21. Geosynthetic Reinforced Soil Embankment Typical Section.

Condition E

Condition E recognizes the possibility that some or portions of some recreational resources are not in their historic location, thus allowing consideration of relocating the resource, without damaging cultural resources. This does not apply to the Valley Railway which is on its historic alignment throughout the Park. However, portions of the Towpath Trail are presently not in their historic location. These areas are shown on Figures 2 through 9 of the Programmatic Environmental Assessment. Some other recreational resources may also not be located in their historic location and could be considered as candidates for relocation, if threatened by the Cuyahoga River or its tributaries.

Materials and Methods Not Being Used

For any condition and technique, there are some materials and methods that will not be used in for riverbank stabilization at CVNP. These include:

- Steel sheetpiling
- Timber sheetpiling
- Vinyl sheetpiling
- Articulated concrete block mattresses
- Grouted riprap
- Paved (asphalt with concrete) linings or slope protection
- Grouted gabions
- Gabions in new locations
- Gabion mattresses
- Reinforced concrete retaining walls
- Timber piling

References

Biedenharn, David S., Charles M. Elliott, and Chester C. Watson. October 1997. The WES Stream Investigation and Streambank Stabilization Handbook.

Collison, A.J.C and A. Simon.

2001a. "Beyond Root Reinforcement: The Hydrologic Effects of Riparian Vegetation on Riverbank Stability." Proceedings of the ASCE Conference on Wetlands and River Restoration, August 27-31, Reno, NV.

2001b. "Quantifying Root Reinforcement of Some Streambanks for Common Riparian Species; Are Willows As Good As It Gets?" Proceedings of the ASCE Conference on Wetlands and River Restoration, August 27-31, Reno, NV.

Fischenich, C. and J. Morrow, Jr. 1999. "Streambank Habitat Enhancement with Large Woody Debris," EMRP Technical Notes Collection. ERDC TN-EMRRP-SR-13), U. S. Army Engineer Research and Development Center, Vicksburg, MS.

Harvey, M.D. 1989. "Meanderbelt Dynamics of the Sacramento River." Proceedings, California Riparian Systems Conference, USDA Forest Service General Technical Report PSW-110, 54-61.

Lagasse, PF., L.W. Zevenbergen, W.J. Spitz and C.R. Thorne.

2003a. Methodology for Predicting Channel Migration, Final Report. Prepared for National Cooperative Highway Research Program, Transportation Research Board, National Research Council. NCHRP Project No. 24-16. Ayres Associates, Inc., Fort Collins, Colorado. 162 pp.

2003b. Handbook for Predicting Stream Meander Migration: Using Aerial Photographs and Maps. Prepared for National Cooperative Highway Research Program, Transportation Research Board, National Research Council.

Sylte, T.L., and Fischenich, J.C. 2000. "Rootwad Composites for Streambank Stabilization and Habitat Enhancement." EMRRP Technical Notes Collection, ERDC TN-EMRRP-SR-21. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

US Department of Agriculture. October 1998, Rev. August 2001. "Stream Corridor Restoration: Principles, Processes and Practices."

Water Engineering & Technology, Inc. (WET). 1988. "Geomorphic Analysis of Sacramento River, Phase I Report: Geomorphic Analysis of Butte Basin Reach, River Mile 174 to River Mile 194" Prepared for U.S. Army Corps of Engineers, Sacramento District, Contract No. DACW05-87-C-0094.